2.5 ON-BOARD NOISE ECM

Electronic countermeasures (ECM) is the division of electronic warfare involving actions to prevent or reduce the enemy's effective use of the electromagnetic spectrum (Reference 20, p. 2). Jamming is the deliberate transmission or retransmission of a signal for the purpose of degrading the reception of expected received signals at a victim electronic system. One of the simplest forms of jamming is noise jamming. Noise jamming is the transmission of a noise-like signal in the victim radar's frequency band for the purpose of masking the expected signal. In the context of *RADGUNS*, the victim system is a threat target tracking radar, and the expected signal is the return signal from the target. In on-board noise jamming the noise jammer is carried by and employed on-board the target platform, as a self protection, or self screening technique.

Noise jamming can be accomplished by either barrage noise jamming—where the jammer's energy is spread over a wide frequency band—or spot jamming—where the energy is concentrated in a narrow band. Barrage jamming increases the probability of covering the radar's signal bandwidth at the cost of lowering the noise power density and the total noise power received by the radar. The *RADGUNS* model characterizes broadband noise jamming over a bandwidth at least as large as the victim radar receiver's noise bandwidth.

2.5.1 Functional Element Design Requirements

This section contains the design requirements necessary to implement the simulation of on-board noise ECM in *RADGUNS*.

a. *RADGUNS* will calculate the received signal power of an on-board broadband noise jammer using a basic radar range equation including effects of jammer power, jammer gains and losses, directional receiver gains, effective bandwidth, and other standard radar parameters.

b. *RADGUNS* will have the capability of simulating up to ten jamming sources in any engagement.

c. *RADGUNS* will have the capability to model broadband noise jamming over a transmitted frequency bandwidth that is either greater than or equal to the radar receiver's noise bandwidth.

d. Both preemptive and reactive jamming tactics will be simulated. The time that a noise jammer is actively jamming will be determined by a predetermined time block for preemptive jamming. In the reactive jamming case, jamming will be initiated when the radar signal at the jammer receiver exceeds a user-specified jammer receiver threshold.

e. An amplitude modulated noise jamming signal shall be employed, at the option of the user. The modulation shall be determined by a user-specified modulation percentage and modulation period.

2.5.2 Functional Element Design Approach

This section describes the design elements that implement the on-board noise ECM design requirements.

The broadband noise jamming power received by the radar is given by (Reference 11, Equation 2.10):

$$S_J = \frac{P_J G_J A_e}{4\pi R_{RJ}^2 L_R} \left[\frac{B_R}{B_J} \right] \qquad [2.5\text{-}1]$$

where:

S_J	=	noise jamming signal power at radar (W)
P_J	=	average jammer power at the antenna input (W)
G_J	=	gain of jammer antenna, including losses (dimensionless)
A_e	=	effective aperture of radar antenna (m^2)
L_R	=	radar receive antenna losses, defined as a number greater than one
R_{RJ}	=	range from jammer to radar (m)
B_R	=	radar receiver noise bandwidth (Hz)
B_J	=	jammer transmit bandwidth (Hz), with $B_J \geq B_R$

The bandwidth ratio represents the effective portion of the jammer bandwidth. The referenced equation also includes a one-way propagation loss factor; however, atmospheric propagation loss is not modeled in the *RADGUNS* ECM FE (the loss factor is assumed to be 1).

The effective radar antenna aperture A_e is defined in terms of radar antenna gain (Reference 11, Equation 1.8) as:

$$A_e = \frac{\lambda^2 G_R}{4\pi} \qquad [2.5\text{-}2]$$

where:

A_e	=	effective antenna aperture (m^2)
G_R	=	radar receiver gain (dimensionless)
l	=	wavelength of signal (m)

Substituting the expression for A_e in [2.5-2] into Equation [2.5-1] gives the equation used by *RADGUNS* for the total on-board noise jammer signal power received by the radar:

$$S_J = \frac{P_J G_J \lambda^2 G_{RJ}}{L_R (4\pi R_{RJ})^2} \left[\frac{B_R}{B_J} \right] \qquad [2.5\text{-}3]$$

Note that G_{RJ} is the radar receiver gain in the direction of the jammer, and for on-board jamming this will be the same as the receiver gain in the direction of the target.

Design Element 5-1: Jammer Power

A nominal jammer power value for use in [2.5-3] is input by the user. Additionally, amplitude modulation may be used to vary the jammer power output level. If a modulation index has been input by the user, the jammer voltage is varied in amplitude by a sinusoidal modulating signal with a user-specified modulation period and index (Reference 21, p. 894).

$$V_m = (1 + m \sin \omega_m t) V_j \tag{2.5-4}$$

where:
- m = modulation index
- w_m = modulation frequency = 2p/modulation period
- t = simulation time (s)
- V_j = nominal jammer voltage = (V)

The jammer voltage is proportional to the square root of the jammer power. The nominal jammer voltage is obtained from the nominal jammer power. Once the modulation is applied, the voltage is squared, yielding the modulated output power. The modulated power is limited to the maximum power output of the jammer:

$$P_{j\,mod} = max\{V_m^2, P_{j\,max}\} \tag{2.5-5}$$

where:
- P_{jmod} = modulated jammer power (W)
- P_{jmax} = maximum jammer power (W)
- V_m = modulated jammer voltage (V), from [2.5-4]

Maximum jammer power is also a user input. If a modulation index is not specified, the jammer output power is set to the nominal jammer power. (For more information on amplitude modulation, see Reference 22, pp. 203 - 205.)

Design Element 5-2: Effective Portion of Jammer Bandwidth

The effective portion of the jammer bandwidth is calculated as the ratio of the radar bandwidth to the jammer bandwidth:

$$\frac{B_R}{B_J}$$

The use of the bandwidth ratio to characterize the effective portion of the jammer bandwidth in the broadband noise jamming Equation [2.6-3] is correct providing the radar bandwidth is contained within the jammer bandwidth. The use of the bandwidth ratio is consistent with the assumption that the *RADGUNS* noise jamming FE models broadband, or barrage jamming.

Note: Definitions of barrage jamming, as opposed to spot jamming, are not consistent in the literature. A definition of barrage jamming that includes the case in which jammer bandwidth is equal to radar receiver bandwidth is given in Reference 11, p. 61.

The *RADGUNS* code does not ensure that the user-entered value for B_J is at least as large as B_R. The code does set the jammer bandwidth to the radar bandwidth, if it has not yet been initialized (or has been initialized as zero). However, jammer bandwidth can be initialized to any value by the user.

The use of the bandwidth ratio in Equation [2.5-3] also assumes that the jamming center frequency is such that the jamming bandwidth covers the frequency range of the radar receiver bandwidth. In *RADGUNS*, jammer frequency is not used in determining the effective portion of the jammer bandwidth. The user must ensure that jammers used to degrade a particular gun system do indeed have the capability to jam in the threat radar frequency range. The use of the bandwidth ratio also assumes the jammer's power is uniformly distributed over the frequency band.

Design Element 5-3: Range to Jammer

The distance from the radar to the jammer is calculated from the jammer position coordinates relative to the radar using the standard distance formula.

$$R_{RJ} = \sqrt{x_{rj}^2 + y_{rj}^2 + z_{rj}^2} \tag{2.5-6}$$

For the on-board jamming case, the jammer coordinates are just set equal to the target coordinates.

Design Element 5-4: Jamming Criteria

The portion of time during the scenario during which a noise jammer is transmitting is determined by whether the desired jamming tactic is preemptive or reactive. If the preemptive (manual) option is selected, the user specifies jammer on and off times, and the jammer is on whenever the current time is within this time block. If the reactive option is selected, a radar signal threshold value is input. In this case, the power of the threat radar at the jammer is calculated, using Equation [2.5-3], with the variables for the radar and jammer reversed:

$$S_{RJ} = \frac{P_R G_{RJ} \lambda^2 G_J}{(4\pi R_{RJ})^2} \tag{2.5-7}$$

where:

where:	S_{RJ}	=	noise jamming signal power at radar (W)
	P_R	=	average jammer power at the antenna input (W)
	G_{RJ}	=	gain of radar antenna in the direction of the jammer (dimensionless)
	G_J	=	gain of jammer antenna (dimensionless)
	l	=	radar signal wavelength (m^2)
	R_{RJ}	=	range from jammer to radar (m)

Equation [2.5-7] also differs from [2.5-3] in that the jammer receiver bandwidth is assumed to include the radar signal bandwidth, giving a bandwidth ratio of 1, and the jammer receiver internal losses are not explicitly considered.

The radar signal power calculated using Equation [2.5-7] is compared with the user-input threshold value to determine if the jammer has detected the threat and the noise jamming signal should be initiated.

Design Element 5-5: Estimated Crossover Range

An estimated crossover, or burn-through range is calculated at the time each jammer becomes active. The ratio of the received noise jamming signal to the received target signal, J/S, is calculated for the current geometry, and the equation is solved for the radar-to-target range at which J/S = 1. The equation used to compute the estimated crossover range is:

$$CR = R_{RJ}\sqrt{\frac{1}{JS}} \qquad [2.5\text{-}8]$$

where R_{RJ} is the radar to jammer range at jamming start, and JS is the ratio of the jammer signal to the target return at jamming start. This equation is derived below.

To compute the J/S ratio, the jamming signal, given by Equation [2.5-3], is divided by the target signal at the radar, so that:

$$JS = \frac{P_J G_J \lambda^2 G_{RJ}}{S_T L_R (4\pi R_{RJ})^2}\left[\frac{B_R}{B_J}\right] \qquad [2.5\text{-}9]$$

where:

JS	=	Jamming signal to target signal ratio (dimensionless)
P_J	=	average jammer power at the antenna input (W)
G_J	=	gain of jammer antenna, including losses (dimensionless)
G_{RJ}	=	radar receiver gain in the direction of the jammer (dimensionless)
l	=	wavelength of signal (m)
S_T	=	target echo signal at the radar receiver (W)
L_R	=	radar receive antenna losses, defined as a number greater than one
R_{RJ}	=	range from jammer to radar (m)
B_R	=	radar receiver noise bandwidth (Hz)
B_J	=	jammer transmit bandwidth (Hz), with $B_J \geq B_R$

The target signal is given by the basic radar range equation (Reference 8, Equations 1.6 and 1.8):

$$S_T = \frac{P_R G_{RT}^2 \lambda^2 \sigma}{L_R (4\pi)^3 R_{RT}{}^4} \qquad [2.5\text{-}10]$$

where: S_T = target signal at the radar receiver (W)
P_R = radar transmitter power (W)
G_{RT} = radar antenna gain in the direction of the target (dimensionless)
l = radar signal wavelength (m)
s = target radar cross section (RCS) (m^2)
L_R = radar receiver internal losses (dimensionless)
R_{RT} = the range from the radar to the target (m)

If Equation [2.5-10] is substituted into [2.5-9], all of the variables can be seen explicitly:

$$JS = \frac{4\pi P_J G_J G_{RJ} R_{RT}^4}{P_R G_{RT}^2 \sigma R_{RJ}^2}\left[\frac{B_R}{B_J}\right]$$

When the jamming source is the target, R_{RJ} is equal to R_{RT} at all times, and G_{RJ}, the gain of the radar receiver antenna in the direction of the jammer, is equal to G_{RT}, the gain of the radar receiver in the direction of the target, so that:

$$JS = \frac{4\pi P_J G_J R_{RJ}^2}{P_R G_{RT} \sigma}\left[\frac{B_R}{B_J}\right] \qquad [2.5\text{-}11]$$

Because *JS* is calculated at the jamming initiation time, Equation [2.5-11] can be rewritten to show the dependence of certain variables on scenario time:

$$JS = \frac{4\pi P_J G_J R_{RJ}^2(t_0)}{P_R G_{RT} \sigma(t_0)}\left[\frac{B_R}{B_J}\right] \qquad [2.5\text{-}12]$$

At time t_1, crossover occurs and *JS* is assumed to be 1.

$$1 = \frac{4\pi P_J G_J R_{RJ}^2(t_1)}{P_R G_{RT} \sigma(t_1)}\left[\frac{B_R}{B_J}\right] \qquad [2.5\text{-}13]$$

Dividing [2.5-11] by [2.5-12] yields:

$$JS = \frac{R_{RJ}^2(t_0)\sigma(t_1)}{R_{RJ}^2(t_1)\sigma(t_0)} \qquad [2.5\text{-}14]$$

Solving for $R_{RJ}(t_1)$ gives:

$$CR = R_{RJ}(t_1) = R_{RJ}(t_0)\sqrt{\frac{1}{JS}}\sqrt{\frac{\sigma(t_1)}{\sigma(t_0)}} \qquad [2.5\text{-}15]$$

The simplified equation [2.5-8] is valid for an on-board jammer (target and jamming source are collocated) when the target RCS, s, does not vary over time.

2.5.3 Functional Element Software Design

This section contains the software design necessary to implement the FE requirements described in Section 2.5.1 and the design approach outlined in Section 2.5.2. It is organized as follows: the first part describes the subroutine hierarchy and gives descriptions of the relevant subroutines; the next part contains logical flow charts and describes important operations represented by each block in the chart; the last subsection contains a description of all input and output data for the functional element as a whole and for each subroutine that implements the On-Board Noise ECM FE.

On-Board Noise ECM Subroutine Design

Figure 2.5-1 shows the calling sequence of the On-Board Noise ECM FE within the entire *RADGUNS* model structure. Functions which implement the FE are in shaded blocks. Each of these subroutines is briefly described in Table 2.5-1. Subroutines which directly implement the On-Board Noise FE appear in shaded blocks.

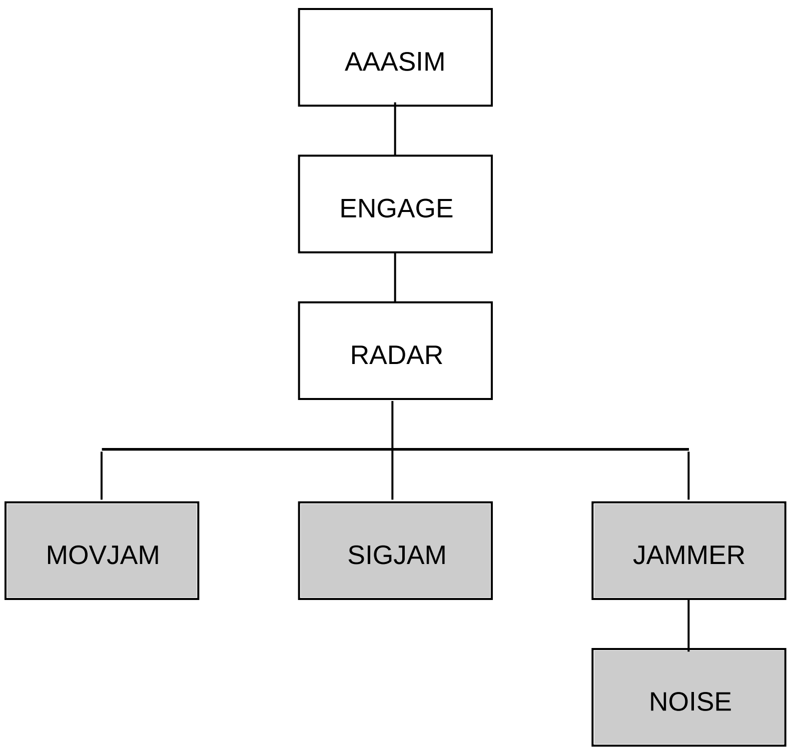

FIGURE 2.5-1. Subroutine Call Hierarchy for On-Board Noise ECM.

TABLE 2.5-1. Module Description for On-Board Noise ECM.

MODULE	DESCRIPTION
AAASIM	Main routine to simulate AAA system
ENGAGE	Controls system while in autotrack mode
RADAR	Calculates signals for target, clutter, and jammers, and sums them in receiver
MOVJAM	Calculates location and velocity of all active jammers
SIGJAM	Computes the antenna gain in the direction of active jammers
JAMMER	Generates jammer signals for up to ten simultaneous jammers
NOISE	Simulates a barrage noise jammer (may be AM)

The functional flow diagram shown in Figure 2.5-2 displays the effect of the ECM FE on the logical flow of subroutine RADAR. RADAR executes this logic once for each radar pulse. Parentheses at the bottom of each block show the subroutine where the indicated action is implemented. If no parentheses appear, the action is executed in subroutine RADAR. Notice that, in an effort to make the ECM FE system independent, the radar receive antenna gain is applied to the jammer signal after it is returned from subroutine JAMMER (Blocks 9 and 10). Thus the computation of the jammer signals at the radar receiver in the individual jammer subroutines by Equation [2.5-3] does not include the radar receiver gain term.

Subroutine SIGJAM calculates the radar antenna gains (both transmit and receive) in the direction of any active jammers (*JAMFAC*). This subroutine is addressed in Section 2.20, Antenna Gain.

The ECM FE is implemented just prior to the summing of signals in the radar receiver in subroutine RCVRT.

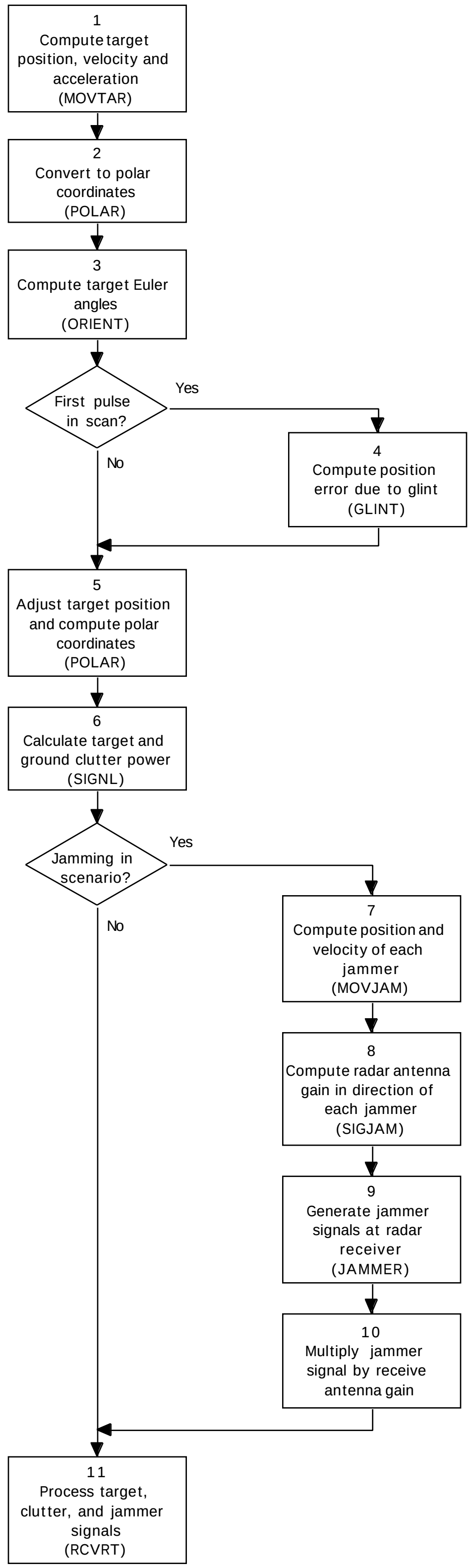

FIGURE 2.5-2. Subroutine RADAR Functional Flow Diagram.

Logical Flow for On-Board Jammer Position Update (MOVJAM). Subroutine MOVJAM updates the position of each jamming source. Subroutine RADAR calls MOVJAM on a pulse-to-pulse basis to compute the current position of all active jammers. The current simulation time along with the target position, velocity, and acceleration are passed to subroutine MOVJAM. Figure 2.5-3 shows the logic flow of subroutine MOVJAM as it applies to an on-board jammer. Portions of subroutine MOVJAM pertaining to other jammer classes are addressed in the corresponding ECM functional elements (see Off-Board and Standoff ECM FEs). The appropriate branch of MOVJAM is executed for each jammer.

Block 1. On-board jamming in *RADGUNS* is selected by specifying a self-protection jammer class option. Four options are available: SPJ (self protect), TOW (towed decoy), EXP (expendable) and SOJ (standoff jamming). SPJ is the appropriate choice for an on-board jammer. For the SPJ option, the jammer position is set to that of the target, so that if the current jammer is an on-board jammer, the jammer location (JXLOC(II,1:3)) is set to the target location (TARGET(1:3,1)).

Block 2. If a jammer class other than SPJ is selected, MOVJAM calculates the jammer position and velocity, in a manner depending on the specific jamming equipment used. The logic flow for these portions of MOVJAM is shown in more detail in the off-board and standoff jamming FEs (1.3.1.2, 1.3.1.3, 1.3.2.2, and 1.3.2.3).

Block 3. If position information has been updated for all jammers, control is returned to subroutine RADAR.

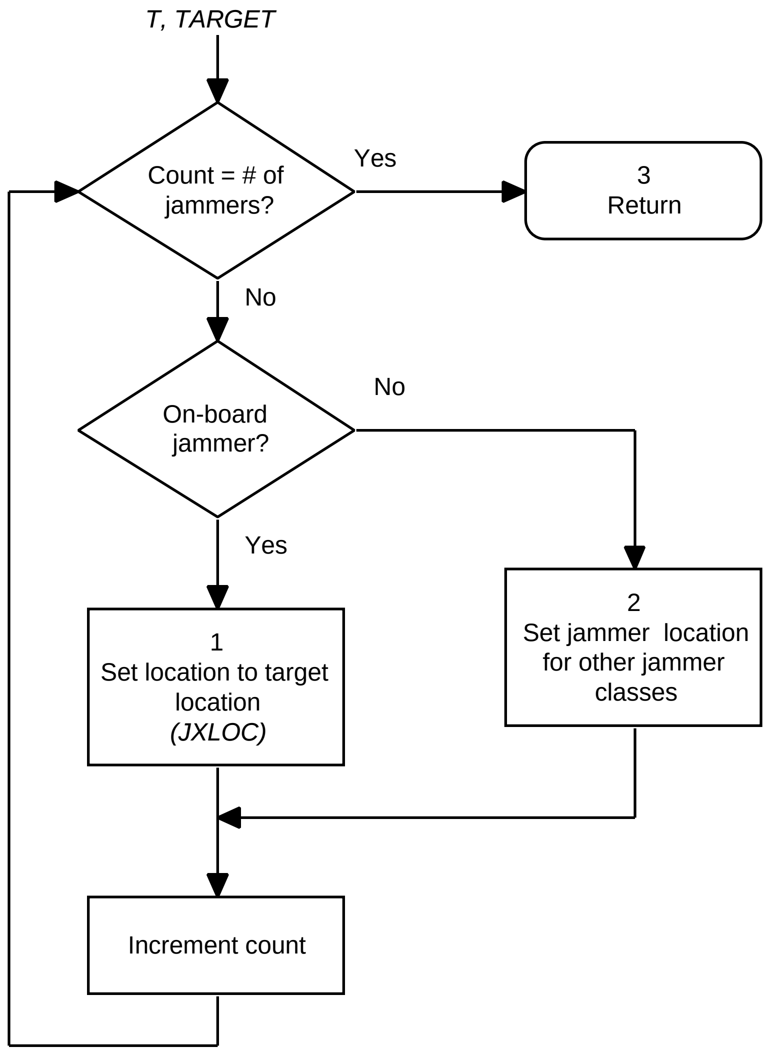

FIGURE 2.5-3. Subroutine MOVJAM Flow Chart for On-Board ECM.

Logical Flow for Subroutine JAMMER. Subroutine JAMMER generates instantaneous jamming signals as a function of time for up to ten simultaneously active jammers. It is called by subroutine RADAR just prior to processing each radar pulse in the threat radar receiver. A subroutine flow chart is shown in Figure 2.5-4. The flow chart shows only those portions of subroutine JAMMER relating to noise jamming. The remainder of the logic flow for JAMMER is discussed in the On-Board Deceptive ECM FE, Section 2.8.3.

Subroutine JAMMER returns the jammer power, return time, frequency, Doppler shift, and pulse width of the jammer return, in the signal environment array SIGENV. Array JAMSRC holds the type of jamming signal; the value "NOI" is returned for noise jamming. All of these values are actually calculated in subroutine NOISE, which is called by JAMMER.

It is possible for an active jammer to have no return. Arrays SIGENV and JAMSRC hold values only for jammer having returns (non-zero signals). The jammer pointer JAMPTR indicates the array elements corresponding to the latest jammer having a return. The array JAMNUM is used to indicate which jammer is responsible for each signal.

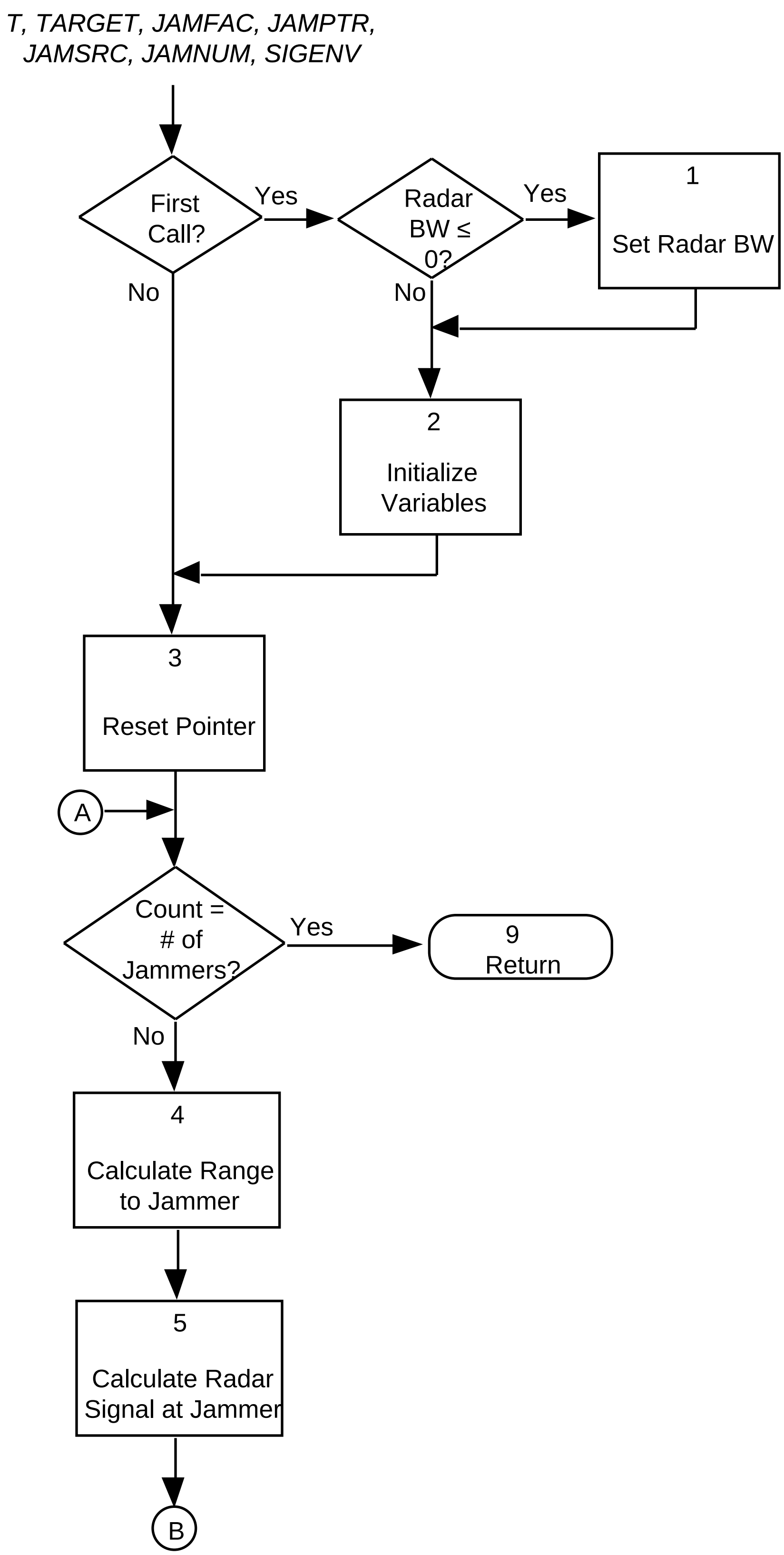

FIGURE 2.5-4. Subroutine JAMMER Flow Chart for Noise Jamming.

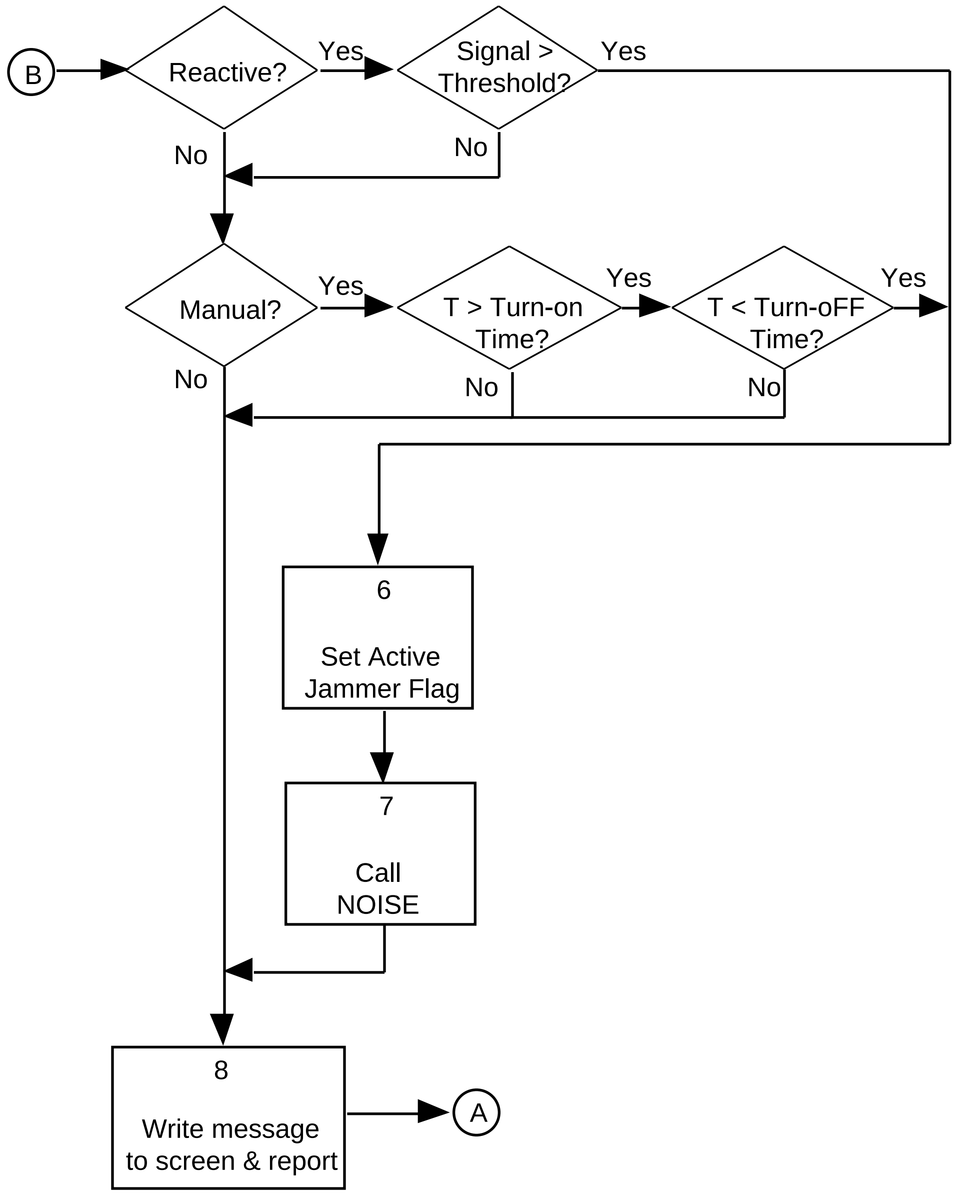

FIGURE 2.5-4. Subroutine JAMMER Flow Chart for Noise Jamming. (Contd).

Blocks 1 and 2 are initializations performed the first time subroutine JAMMER is called for each jammer.

Block 1. If the threat radar bandwidth has not yet been initialized (is less than or equal to zero), it is set to 6 MHz.

Block 2. The user may specify up to ten jammers. Arrays FIRSTJ, FIRSTR, CR, and JAMMED are ten element arrays, each element of which corresponds to a separate jammer. For the number of jammers specified by the user (NUMJAM), the following flags and variables are initialized. FIRSTJ flags are set to indicate that jamming has been initiated, FIRSTR flags are set to indicate that the technique local variables need to be reset, the crossover ranges (CR) used in noise jamming are set to zero, and JAMMED flags are cleared to indicate that the jammers are not yet active.

Block 3. The current jammer pointer, JAMPTR, is reset to zero each time subroutine JAMMER is called. Blocks 4 through 8 are executed once for each jammer input by the user.

Block 4. The range from the radar to the current jammer is calculated using Equation [2.5-6] and stored in JAMRG.

Block 5. The radar signal at the jammer receiver is calculated with Equation [2.5-7].

Block 6. If the user has selected the reactive jamming mode and the jammer receiver threshold has been exceeded, or if manual mode has been selected and the simulation time exceeds the turn on time, the JAMMED flag corresponding to the current jammer is set to indicate that jammer is active. In the reactive case, if the JAMMED flag has been previously set but the radar signal no longer exceeds the threshold, a period of 0.5 s is allowed before the jamming is discontinued. If jamming is not active, execution resumes with Block 8.

Block 7. Subroutine NOISE is called. If the calculated signal is non-zero, NOISE updates the jammer signal environment array (SIGENV), the type of jamming signal (JAMSRC), the mapping JAMNUM, and the array pointer for the current jammer signal (JAMPTR).

Block 8. If the current jammer has just become active, subroutine EVENT is used to record a “jamming initiated” event. The jammer number, class, and type as well as the time jamming was initiated are written to both the screen and the output file. In the case of noise jamming, the jammer burn-through range is also written. If the jammer is active and the jammer received power has failed to exceed the threshold for 0.5 s in reactive mode, or the simulation time exceeds the turn off time in manual mode, subroutine EVENT records a ‘jamming ended’ event. The jammer number, class, type, and time that jamming ended are written to both the screen and the output file.

Block 9. If signals have been calculated for each active jammer, control returns to subroutine RADAR where each jammer signal is amplified by the threat radar receive antenna gain and processed with the other radar returns in the receiver.

Logical Flow for Subroutine NOISE. Subroutine NOISE simulates a barrage noise jammer that spreads a noise-like jamming signal over a frequency bandwidth greater than or equal to the bandwidth of the radar receiver to obscure an expected target return. A subroutine flow chart is shown in Figure 2.5-5 and described below.

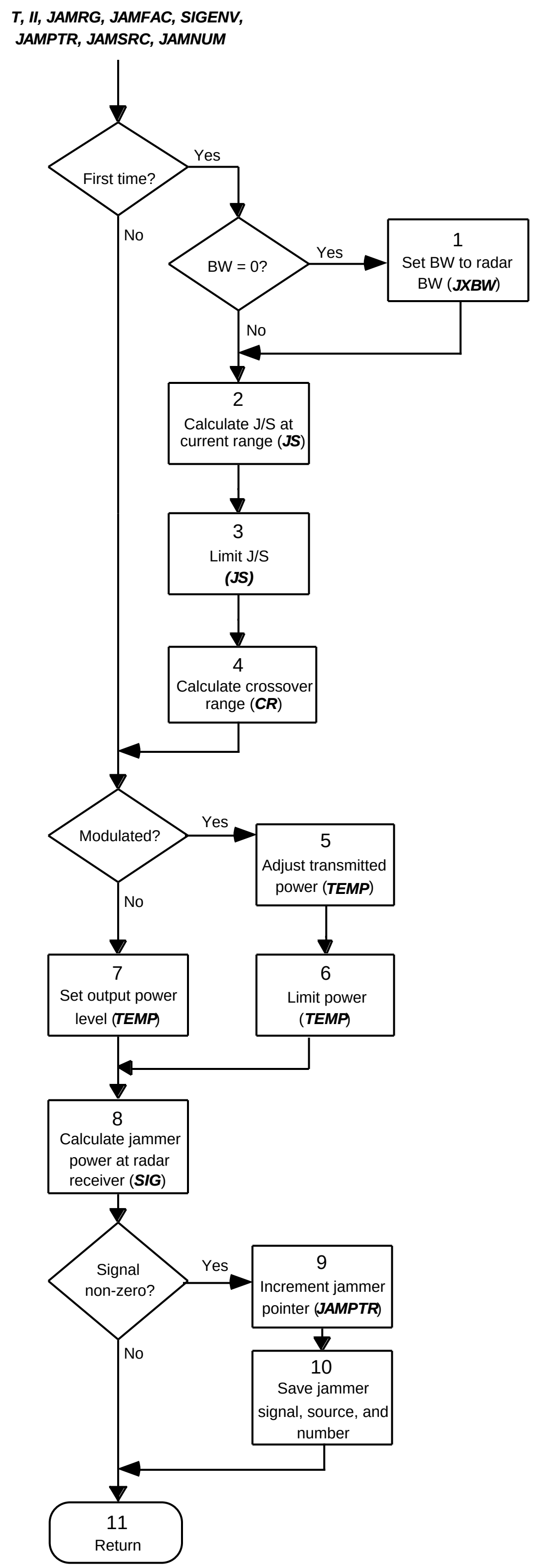

FIGURE 2.5-5. Subroutine NOISE Flow Chart.

The first time subroutine JAMMER is called, the elements in array FIRSTR are set for the number of jammers specified by the user indicating that the technique-specific parameters need to be initialized. These initializations are implemented in Blocks 1 through 4 the first time subroutine NOISE is called for each noise jammer specified.

Block 1. If the jammer bandwidth is zero, it is set to the bandwidth of the threat radar.

Block 2. The jammer signal at the threat radar receiver is calculated via Equation [2.5-3]. The J/S ratio is obtained by dividing the jammer signal by the target signal which is passed in SIGENV(0,1).

Block 3. The J/S ratio is limited to a minimum of 1×10^{-20}.

Block 4. The crossover, or burn-through range is the range at which the skin reflection from the target is equal to the background noise (J/S of 1). The current J/S ratio is calculated using Equation [2.5-9], and the crossover range is calculated using [2.5-8]. An upper limit of 999999.9 is applied to the crossover range.

Blocks 5 through 10 are executed each time subroutine NOISE is called.

Blocks 5 and 6. Amplitude modulation may be used to vary the jammer output power level and create a more random signal. If a modulation index has been input by the user, the jammer voltage is varied in amplitude by a sinusoidal modulating signal with a user specified modulation period (JXMODP) and index (JXMODA), as in Equation [2.5-4]. The modulated power is then obtained by squaring the modulated voltage. Modulated power is further limited by the maximum jammer power (JXMAXP), as in Equation [2.5-5].

Block 7. If the user did not input a modulation index, the jammer signal output power is set to the nominal jammer power specified by the user (JXPWR).

Block 8. The jammer signal at the radar receiver (SIG) is calculated using Equation [2.5-3].

Blocks 9 and 10. If the signal is non-zero, function INCJAM is used to increment the current jammer pointer (JAMPTR) and the signal level, source, and number are stored in SIGENV, JAMSRC, and JAMNUM, respectively. For a noise jammer, the radar's PRI is stored in the 'pulse width' column of SIGENV.

Block 11. Arrays SIGENV, JAMSRC, and JAMNUM are returned to subroutine JAMMER.

On-Board Noise ECM Inputs and Outputs

This section identifies the input and output data associated with the On-Board Noise ECM FE. Table 2.5-2 shows the FE output.

TABLE 2.5-2. Outputs of On-Board Noise ECM FE.

Variable Name	Description
SIGENV	Signal environment array; specifically, the elements SIGENV(x,1) and SIGENV(x,5) are output by NOISE. SIGENV(x,1) contains the jammer signals; SIGENV(x,5) contains the radar pulse repetition interval (PRI)
JAMSRC	Type of jamming signal. Noise jamming is coded 'NOI'
JAMPTR	Pointer showing last jammer for which a (non-zero) signal value was calculated
JAMNUM	Array mapping identifying those jammers for which results were reported
CR	Estimated target burn-through range, when a jammer is first turned on

Table 2.5-3 displays user-defined input data which affect the On-Board Noise ECM FE.

TABLE 2.5-3. User Inputs.

Variable Name	User Options	Description
JXCLAS	SPJ - self protection jammer TOW - towed jammer or decoy EXP - expendable jammer SOJ - standoff jammer	Jammer class. SPJ is the option for on-board jamming
JAMODE	MAN - manual start/stop times REA - reactive based on received signal	Jammer employment mode
TIMJAM	Times (s)	Manual jamming turn on/turn off times
JTHRES	dB (mW)	Jammer receiver threshold for reactive jamming
JAMTYP	NOI- noise jammer INV - inverse gain RGW - range gate walk-off RPT - simple repeater SWA - swept audio REF - passive reflector	Jammer technique. NOI is the option for noise jamming
JXMAXP	(W)	Maximum transmit power
JXPWR	(W)	Nominal transmit power
JTXAGN	(dB)	Transmit antenna gain
JRXAGN	(dB)	Receive antenna gain
JXBW	(MHz)	Jammer bandwidth
JXMODA	0-100	Modulation percentage
JXMODP	(s)	Modulation period

Several unit conversions are done in subroutine INPJAM, before variables are used in the ECM FE equations. The jammer receiver threshold is converted from dB mW to W, the jammer transmit and receive antenna gains are converted from dB to linear numbers, the jammer bandwidth is converted from MHz to Hz, and the modulation percentage is converted to a fraction between 0 and 1.

Subroutine MOVJAM inputs and outputs which affect the On-Board Noise ECM FE are shown in Table 2.5-4.

TABLE 2.5-4. Subroutine MOVJAM Inputs and Outputs.

SUBROUTINE: MOVJAM					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
TARGET	Argument	Target position array	JXLOC	COMMON	Jammer location array
NUMJAM	COMMON	Number of jammers			
JXCLAS	COMMON	Jammer class			

Table 2.5-5 lists variables input to and output from subroutine JAMMER. The arrays JAMPTR, JAMSCR, JAMNUM and the jammer signal portion of array SIGENV are actually calculated in subroutine NOISE but are passed back to RADAR through arguments in JAMMER. Values of CR are also calculated in NOISE but are written to an event message by JAMMER. The inputs TARGET and JXCLAS are used by JAMMER only for the purpose of writing event messages.

TABLE 2.5-5. Subroutine JAMMER Inputs and Outputs.

SUBROUTINE: JAMMER					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Variable**	**Type**	**Description**
JAMFAC	Argument	Radar antenna gain in direction of jammer, from SIGJAM	JAMFAC	Argument	Radar antenna gain in direction of jammer, used by NOISE
SIGENV	Argument	Signal environment array: SIGENV(0,1): target signal, (W) computed in SIGNL, passed to NOISE	JAMPTR	Argument	Pointer showing last jammer for which a (non-zero) signal value was calculated
NUMJAM	Common	Number of jammers	JAMSRC	Argument	Type of jamming signal. Noise jamming is coded ‘NOI’
JAMODE	Common	Jammer mode of operation: MAN (manual) or REA (reactive)	JAMNUM	Argument	Array mapping identifying those jammers for which non-zero signal results were reported

TABLE 2.5-5. Subroutine JAMMER Inputs and Outputs. (Contd.)

SUBROUTINE: JAMMER					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Variable**	**Type**	**Description**
JTHRES	Common	Jammer receiver threshold (W)	SIGENV	Argument	Signal environment array: SIGENV(x,1): jammer signal (W @ radar receiver), calculated in NOISE SIGENV(x,5): radar PRI, entered in NOISE
TIMJAM	Common	Manual jammer ON/OFF times (s)	JAMRG	Argument	Range from radar to jammer, output to NOISE
JXLOC	Common	Jammer position relative to radar, computed in MOVJAM	CR	Common	Noise jammer crossover range (m)
JRXAGN	Common	Jammer receive antenna gain (dimensionless)			
PTX	Common	Threat radar transmitted power (W)			
WLNTH	Common	Threat radar wavelength (m)			
RDRBW	Common	Threat radar noise bandwidth (Hz)			
T	Argument	Simulation time (s), from RADAR			
TARGET	Argument	Target *x*, *y*, *z* position, velocity, and acceleration (m, m/s, m/s^2), from MOVTAR			
JAMTYP	Common	ECM technique: NOI (Noise) option applies to noise jamming.			
JXCLAS	Common	Jammer class: SPJ = On-board			

Table 2.5-6 lists variables input to and output from subroutine NOISE.

TABLE 2.5-6. Subroutine NOISE Inputs and Outputs.

SUBROUTINE: NOISE					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
T	Argument	Simulation time (s)	JAMPTR	Argument	Pointer showing last jammer for which a (non-zero) signal value was calculated
JAMRG	Argument	Range from radar to jammer (m), from JAMMER	JAMSRC	Argument	Type of jamming signal. Noise jamming is coded 'NOI'
JAMFAC	Argument	Radar antenna gain in direction of jammer, from SIGJAM	JAMNUM	Argument	Array mapping identifying those jammers for which non-zero signal results were reported
SIGENV	Argument	Signal environment array: SIGENV(0,1): target signal, (W) from SIGNL, via JAMMER	SIGENV	Argument	Signal environment array: SIGENV(x,1): jammer signal (W @ radar receiver) SIGENV(x,5): radar PRI
JTXAGN	Common	Jammer transmit antenna gain (dimensionless)	CR	Common	Noise jammer crossover range (m)
JXBW	Common	Jammer Bandwidth (Hz)			
JXMAXP	Common	Jammer maximum transmitter power (W)			
JXMODA	Common	Jammer amplitude modulation index			
JXMODP	Common	Jammer modulation period (s)			
JXPWR	Common	Jammer nominal transmitter power (W)			
RDRBW	Common	Threat radar noise bandwidth (Hz)			
TOTLOS	Common	Threat radar internal signal losses			
WLNTH	Common	Threat radar wavelength (m)			

2.5.4 Assumptions and Limitations

RADGUNS models only the effects of jamming on automatic target tracking. Jamming is not considered in simulating target acquisition.

The jammer antenna boresight is assumed to be aimed at the radar, and a single transmitter antenna gain value, representing the jammer main lobe gain, is used for all jammer signal calculations. A single jammer receiver gain value is used in computing the radar signal receiver at the jammer.

The capability of a jammer to counter a frequency-agile radar is not addressed, and threat radar frequency agility is not modeled. RADGUNS assumes that the jamming bandwidth is centered at the radar receiver noise bandwidth throughout the engagement.

The noise jamming model is valid for a jamming bandwidth that is greater than or equal to the threat radar receiver noise bandwidth. For noise jamming, the simulation assumes that the user-entered jammer bandwidth value satisfies this requirement. There is no restriction in the RADGUNS code to prevent the use of a jammer bandwidth that is less than the radar bandwidth.

RADGUNS assumes that noise jamming power is uniformly distributed over the jammer bandwidth.